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(54) **Accelerometer assembly with evaluation circuit.**

(57) A microaccelerometer package (10) is provided for use in on-board automotive safety control and navigational systems. The microaccelerometer package (10) is constructed so as to minimize the influence of extraneous mechanical stress and vibrational resonance on the micromachined accelerometer. The microaccelerometer package (10) includes a rigid housing (10) in which there is a cavity for receiving the micromachined accelerometer unit (16) and the signal-processing circuitry (24). The lower surface (46) of the cavity is interrupted by a recess (34) projecting below the plane of the lower surface (46). The micromachined accelerometer unit (16) is secured within the recess (34) so as to be below the plane of the lower surface (46). The signal-processing circuitry (24) is supported by a substrate (24) which is secured to the lower surface of the cavity. One edge of the substrate (24), on which are disposed a number of wire bond sites, partially projects over the accelerometer unit (16) within the recess (36), but no further than a corresponding number of wire bond sites (26) on the micromachined accelerometer unit (16). Electrically interconnecting the wire bond sites of the signal-processing circuitry and the micromachined accelerometer unit (16) are a corresponding number of electrical conductors (28,30).

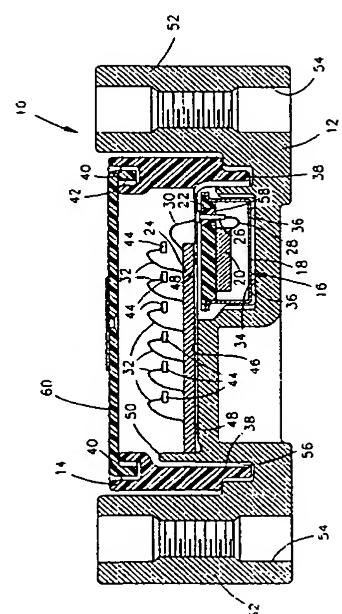

FIG.1

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This invention relates to an accelerometer assembly, for example a microaccelerometer packaging having improved stress isolation and ruggedness such that the microaccelerometer assembly is suitable for use in an automotive environment.

An accelerometer is one of the primary sensors used in on-board automotive safety control systems and navigational systems, particularly crash sensing systems. Examples of such automotive applications include anti-lock braking systems, active suspension systems, supplemental inflatable restraint systems such as air bags, and seat belt lock-up systems. An accelerometer is a device which measures acceleration, or more accurately, accelerometers measure the force that is exerted by a body as the result of a change in the velocity of the body. A moving body possesses inertia which tends to resist the change in velocity. It is this resistance to any change in velocity that is the source of the force which is exerted by the moving body. This force is directly proportional to the acceleration component in the direction of movement when the moving body is accelerated.

In one conceptual form of a conventional accelerometer, a mass is suspended between two spring members which are coaxially attached on opposite sides of the mass. The mass is maintained in a neutral position so long as the system is at rest or is in motion at a constant velocity. When the mass-spring support system undergoes a change in velocity in the direction of the axis of the springs, i.e. an acceleration or deceleration parallel to the spring axis, the spring mounted mass will resist the movement because of its inertia. This resistance to the change in velocity will force one of the springs to be in tension and the other to be in compression. Accordingly, the force acting on one spring is equal but opposite in magnitude to the force acting upon the other.

In a micromachined accelerometer employing piezo-resistive microbridges, acceleration in the plane perpendicular to a plane through the proof mass and microbridges can be detected. This causes a compressive or tensile load on portions of the oppositely disposed piezo-resistive microbridges supporting the proof mass, depending on which direction it comes from in that plane. It is the accelerating force on the support system for the proof mass and the proof mass inertia which generates compressive or tensile loads on the piezo-resistive microbridges. In turn, the resulting compressive or tensile loads change electrical resistance of piezo-resistors in the microbridges. This change in electrical resistance can be sensed to determine the magnitude of the acceleration component perpendicular to the plane of the common axis shared by the pair of piezo-resistive microbridges. This type of piezo-resistive microbridge accelerometer is attractive for precision measurements.

Such precision products could be quite useful in automotive applications. However, they must be adequately packaged to protect the micromachined accelerometer from a vehicle's harsh environment. The accelerometer should not only be isolated from the mechanical stresses associated with mounting the package, but must also be protected during use from extraneous road and vehicle vibrations. Moreover, the package must isolate the accelerometer from the harsh automotive environment, such as salt, grease, dust and moisture. In addition, it should be easy to assemble in order to improve quality and durability and to reduce cost. Still further, the proof mass, microbridges and their supporting system have to be packaged, and/or the package itself supported, in a manner wherein the microaccelerometer will only be sensitive to those particular external forces which it is intended to detect. For example, if it is to detect acceleration or deceleration of the vehicle itself, one would not ordinarily want it also to detect jarring of the vehicle due to a bump or chuck hole in a road surface. In addition, it would be desirable if the packaging were small and compact while also providing an inert protective atmosphere for the micromachined accelerometer. Lastly, it would also be advantageous if such a packaging means facilitated early testing of the device while also being amenable to high volume, low cost automotive production techniques.

The present invention seeks to provide an improved accelerometer assembly.

According to an aspect of the present invention, there is provided an accelerometer assembly as specified in claim 1.

The invention can provide a microaccelerometer packaging which is constructed so as to isolate the micromachined accelerometer from mechanical stresses associated with mounting the device and extraneous vibrations, while also providing a testable assembly which is small, compact and amenable to automotive production techniques.

The present invention may provide a microaccelerometer package which is suitable for use in automotive applications and manufacturable by automotive production techniques; a microaccelerometer package capable of isolating the micromachined accelerometer from extraneous stresses, while also being small, light-weight, and amenable to mass production techniques; and/or a microaccelerometer package employing a housing in which both the micromachined accelerometer and the signal-processing circuitry necessary to condition the output signal of the micromachined accelerometer can be enclosed.

The invention can also provide an assembly in which the micromachined accelerometer and its signal-processing circuitry is positioned within the housing so as to minimize the length of the electrical connectors needed to interconnect the micromachined accelerometer with the circuitry; in which the signal-processing circuitry remains accessible for final trimming and tuning procedures prior to sealing the assembly closed; and/or a microaccelerometer packaging process which can utilize automated wire bond technology for electrically connecting the micromachined accelerometer with the signal-processing circuitry.

In a preferred embodiment, a microaccelerometer package is provided which is suitably rugged for use in on-board automotive safety control and navigational systems. The microaccelerometer package is constructed so as to minimize the influence of extraneous road and vehicle vibrations on the micromachined accelerometer. As a result, a more reliable signal output is provided by the micromachined accelerometer for indicating an automobile's acceleration or deceleration. The microaccelerometer package may include a rigid housing in which there is a cavity for receiving the micromachined accelerometer unit and the signal-processing circuitry. The bottom of the cavity may be defined by a lower surface. The lower surface may be generally planar, being interrupted by a recess which projects below the plane of the lower surface.

In the preferred embodiment, the micromachined accelerometer unit is secured within the recess in the lower surface of the housing cavity so as to be below the plane of the lower surface. The micromachined accelerometer unit comprises a sensing element contained within a hermetically-sealed canister. Disposed along one edge of the canister are a number of wire bond sites from which the output signal generated by the sensing element can be transmitted through the canister walls to the signal-processing circuit. The electrical leads extend upwardly from the canister toward the cavity.

The signal-processing circuitry is preferably supported by a substrate which is secured to the lower surface of the cavity. One edge of the substrate may partially project over the recess and the accelerometer unit therein, but preferably no further than the wire bond sites on the micromachined accelerometer unit. The signal-processing circuitry has a number of wire bond sites corresponding to the wire bond sites of the micromachined accelerometer. These wire bond sites are preferably located adjacent the projecting edge of the substrate such that the wire bond sites of the signal-processing circuitry are proximately located to the wire bond sites of the accelerometer unit, both of which are near the plane defined by the lower surface of the cavity. Proximity of the corresponding wire bond sites facilitates automated procedures for attaching the electrical conductors to the wire bond sites.

In addition, electrical contacts may extend through a wall of the housing through which the conditioned signal from the signal-processing circuitry is transmitted for subsequent use with the associated automotive system, such as a supplemental inflatable restraint system, an anti-lock braking system, an active suspension system, or a seat belt lock-up system. The signal-processing circuitry and micromachined accelerometer unit are then preferably coated with a passivation compound, and the housing sealed from the automotive environment with a suitable lid.

A particularly advantageous feature of this embodiment is that both the micromachined accelerometer unit and its signal-processing circuitry are enclosed within the housing in a manner which minimizes space requirements. The micromachined accelerometer unit and the signal-processing circuitry are also positioned and secured relative to each other so as to reduce the possible relative movement therebetween. As such, vibration of each component is inhibited as well as the effects of extraneous vibrations on the micromachined accelerometer unit, therefore the accelerometer unit may still be capable of properly sensing the automobile acceleration or deceleration. Such advantages are particularly desirable for the hostile automotive environment for which the micromachined accelerometer is intended.

Another distinct advantage of this embodiment is that the electrical connectors between the micromachined accelerometer unit and the signal-processing circuitry need only extend over the projecting edge of the signal-processing circuitry's substrate in order to reach the corresponding wire bond sites of the micromachined accelerometer unit. Both groups of wire bond sites are preferably located near the plane defined by the lower surface of the cavity, and therefore little vertical projection of the electrical conductors is required. As noted above, minimizing the length of the electrical conductors facilitates automated procedures for attaching the electrical conductors to the wire bond sites.

A further advantage is that the signal-processing circuitry can remain accessible after being mounted within the cavity until the passivation treatment is applied. Where thick film circuitry is utilized, such an advantage allows for final trimming of the resistors in the circuit for the purpose of correcting any signal output errors resulting from manufacturing and processing tolerances of the individual elements of both the circuit and the

micromachined accelerometer. In addition, the packaging means can provide a small compact assembly which is amenable to automotive production techniques.

An embodiment of the present invention is described below, by way of illustration only, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of the construction and arrangement of an embodiment of micromachined accelerometer package;

Figure 2 is a cross-sectional plan view of the micromachined accelerometer unit of Figure 1; and

Figure 3 is a cross-sectional side elevational view of the micromachined accelerometer unit of Figure 1.

With reference to Figure 1, a microaccelerometer package 10 is shown for housing a microaccelerometer unit 16 and its associated hybrid thick film circuitry (not shown) which is formed on an alumina substrate 24 and which includes a thick film circuit and at least one integrated circuit. The microaccelerometer unit 16 includes a micromachined accelerometer sensing element 20. The microaccelerometer unit 16 is electrically connected to the hybrid thick film circuitry by one or more electrically conducting leads 30. The leads 30 allow the micromachined accelerometer's input power and output signal to be transmitted to and from the hybrid thick film circuitry for signal conditioning and processing.

The thick film circuit is deposited onto the alumina substrate 24 using conventional means such as silk screening techniques, although other techniques could also be used. The conditioned output signal is thereafter transmitted from the hybrid thick film circuitry through electrical leads 32 to six terminal blades 44 which extend through a wall of the microaccelerometer package 10 for subsequent connection in the associated vehicle control system.

The microaccelerometer package 10 includes a backplate 12 having a pair of oppositely disposed mounting structures 52. The backplate 12 is preferably a die cast aluminium which provides rigidity to the microaccelerometer package 10. This rigidity reduces the stress transferred to the microaccelerometer unit 16, such stress generated by attachment of the mounting structures 52 against "uneven" mounting structures within the vehicle. Testing has indicated that the die cast aluminium backplate 12 is also able to remain rigid and unaffected by vibrational noise up to and beyond 3000 Hertz at levels that would otherwise input a false vibration signal to the microaccelerometer unit 16. Each mounting structure 52 has a threaded bore 54 therethrough for mounting the microaccelerometer package 10 to a suitable structure within the vehicle. Between the mounting structures 52 lies a planar surface 46 for supporting and securing the substrate 24 within the microaccelerometer package 10. Surrounding the entire planar surface 46 so as to lie between the planar surface 46 and each mounting structure 52 is a trough 56, the purpose of which is described below.

Disposed at one end of the planar surface 46 and adjacent the trough 56 is a recess 34. The recess 34 is centrally located on one edge of the planar surface 46 such that the planar surface 46 is substantially U-shaped. The recess 34 projects below the planar surface 46 by a distance sufficient to receive the microaccelerometer unit 16 comprising a canister 18 and cover 22 which house a micromachined accelerometer sensing element 20. The canister 18 is preferably formed from an appropriate steel, but other suitable materials such as a nickel may be used. The cover 22 is formed from a low expansion KOVAR material but could be foreseeably formed from a steel or other material in the future. Both the canister 18 and cover 22 are electroless nickel plated but could be plated with other appropriate metals suitable for bonding, such as gold, silver or copper.

The canister 18 and cover 22 are hermetically attached to each other, thus providing a rigid and closed structure for the micromachined accelerometer sensing element 20, the advantages of which are discussed more fully later. The recess 34 is generally square-shaped as viewed from above, as is the canister 18 for housing the micromachined accelerometer sensing element 20, thereby to fit closely within the recess 34. The canister 18 is secured to the floor of the recess 34 by a suitable bonding agent which is applied evenly onto the surface of the floor of the recess 34 for uniform adhesion, and is preferably a primerless silicone adhesive material such as Dow Corning QX-6265. Such a silicone adhesive is more resilient than an epoxy or other rigid mounting material, such that adhesive-transmitted mechanical stresses are greatly reduced. In addition, this layer of resilient adhesive also prevents transfer of any stresses which may arise during the mounting of the package 10 with the mounting structures 52. Spacing means 36 are employed to ensure the uniform spacing of adhesive so as to prevent tilting of the micromachined sensing element 20 from uneven distribution of the adhesive or to prevent the adhesive joint between backplate 12 and canister 18 from becoming too thin and non-resilient.

As best seen in Figure 3, the micromachined accelerometer sensing element 20 is bonded to the cover 22 with a silicone die attach adhesive, such as Dow Corning HIPEC SDA6501 compound. This compound is a high purity silicone with the addi-

tional advantage of avoiding ionic contamination of the sensitive electronic circuitry. The micro-machined accelerometer sensing element 20 is electrically connected with a number of aluminium conductors 28, approximately 0.05 mm (0.002 inches) in diameter, to a like number of pins 26 which extend through the cover 22. Gold wire connectors of about 0.025 mm to about 0.05 mm (about 0.001 to about 0.002 inches) diameter could be substituted for the aluminium conductors 28 if a suitable plating is first deposited onto the pins 26. The pins 26 are also bonded to the cover 22 with an appropriate glass, such as Corning Glass =7052 which is suitable for a metal-to-glass seal and common in the hermetic sealing industry, indicated by reference numeral 58.

Each pin 26 serves as a wire bond site and has a corresponding wire bond site provided on the micromachined accelerometer sensing element 20. The aluminium conductors 28 are formed using known wire bonding techniques. The wire bonding process attaches one end of the aluminium conductor 28 either to the micromachined accelerometer sensing element 20 or to the pin 26, and then dispenses the aluminium conductor 28 as it travels to the other wire bond site where it secures the opposite end of the aluminium conductor 28.

The packaging process for the micromachined accelerometer unit 16 encompasses hermetically sealing the microaccelerometer unit 16 using a conventional welding process. In being a hermetically sealed microaccelerometer unit 16, the micromachined accelerometer sensing element 20 is protectively housed, and is dry passivated with no requirement for the sensing element itself to be a hermetically sealed device.

The alumina substrate 24 on which the hybrid thick film integrated circuitry is deposited (as shown best in Figure 1) is positioned on the planar surface 46 and is permanently secured thereto at several locations with the preferred silicone adhesive material, such as Dow Corning QX-6265. Preferably, the silicone adhesive is applied evenly onto the surface 46 for uniform adhesion. Spacing means 48 are again preferably employed to ensure the uniform spacing of adhesive under the alumina substrate 24 so as to prevent tilting of the substrate 24 from uneven distribution of the adhesive. The alumina substrate 24 is positioned so as to abut one or more vertical projections 50 arising from the planar surface 46 adjacent the trough 56, so that the alumina substrate 24 projects partially across the recess 34 so that approximately half of the microaccelerometer unit 16 remains exposed, including the portion which includes the pins 26.

As noted before, the planar surface 46 is substantially U-shaped, such that the alumina substrate 24 is vertically supported along its entire length, being supported by the planar surface 46 only along its lateral edges on either side of the recess 34. The substrate 24 does not contact the microaccelerometer unit 16, but is suspended above the microaccelerometer unit 16 by the planar surface 46 so as to isolate the microaccelerometer sensing element 20 from vibrational and mechanical stresses. As shown, the alumina substrate 24 is bonded to the planar surface 46 such that the hybrid thick film circuitry is firmly secured to the planar surface 46 of the aluminium backplate 12, even with the provision of the recess 34.

Disposed along the edge of the substrate 24 which projects over the recess 34 are a number of wire bond sites (not shown) which correspond to the number of pins 26 for the microaccelerometer unit 16. The pins 26 serve as wire bond sites for the microaccelerometer unit 16. Formed between the wire bond sites of the alumina substrate 24 and the microaccelerometer unit 16 are the corresponding number of electrical leads 30. The leads 30 are preferably of aluminium and approximately 0.2 mm to 0.25 mm (0.008 to 0.010 inches) in diameter. As described previously, the leads 30 are formed using known wire bonding techniques, although other suitable methods could also be employed. The wire bonding process is further facilitated by the proximity of the wire bond sites of the alumina substrate 24 and the pins 26.

A housing 14 is a secured to the aluminium backplate 12 by inserting a lower edge 38 into the trough 56 formed in the aluminium backplate 12, thereby forming a cavity within the microaccelerometer package 10. Before the housing 14 is attached to the backplate 12, a suitable bonding agent, such as Dow Corning Q3-6611, is deposited in a suitable quantity into the groove 56 so as to provide complete adhesive contact along and between the entire length of edge 38 and groove 56. The housing 14 is preferably formed from a rigid light-weight material, such as Celanex 3300D, a 30% glass filled polyester. The six terminal blades 44 noted above extend through one wall of the housing 14 by which the conditioned micromachined accelerometer signal can be transmitted to the associated vehicle control system. Six corresponding electrical leads 32 interconnect the alumina substrate 24 with the terminal blades 44. Similarly to the leads 30 between the microaccelerometer unit 16 and the alumina substrate 24, the leads 32 are each approximately 0.2 mm to 0.25 mm (0.008 to 0.010 inches) in diameter and are formed using known wire bonding techniques. The terminal blades 44 are preferably formed from a copper alloy for good electrical conductivity, but are tin plated outside of the housing 14 for good solderability to an external

electronic vehicle control system, while being preferably aluminium clad inside the housing 14 for reliable wire bonding with the leads 32.

Along the upper periphery of the housing 14 is a groove 40. The groove 40 receives a lip 42 which extends downwardly from a cover 60 which encloses the cavity formed by the housing 14 and backplate 12. Before the cover 60 is attached to the housing 14, a high temperature vulcanizing silicone passivation gel (not shown), such as Dow Corning Q3-6635, is deposited into the cavity to protect both the substrate 24 and the microaccelerometer unit 16. Such a protective gel is very compliant for purposes of minimizing stresses due to thermal expansion and contraction of the gel in relation to the internal components of the microaccelerometer package 10. An air gap of approximately 1.6 mm (1/16 of an inch) is left between the cover 60 and the silicone passivation gel to provide for thermal expansion and the like. In addition, before the cover 60 is attached to the housing 14, a suitable bonding agent, such as the Dow Corning Q3-6611, is preferably disposed in a suitable quantity into groove 40 so as to provide complete adhesive contact along and between the entire length of lip 42 and groove 40.

A significant advantage of the embodiment described above is that both the microaccelerometer unit 16 and the hybrid thick film circuitry are enclosed within the microaccelerometer package 10 in a manner which minimizes the weight and space requirements of the package 10. The microaccelerometer unit 16 and the substrate 24 supporting the hybrid thick film circuitry are also positioned and secured relative to each other so as to diminish the effects of relative movement therebetween. As such, vibration of either component is inhibited from being transmitted as an extraneous vibration to the micromachined accelerometer sensing element 20, which significantly reduces the mechanical and vibrational stresses associated with mounting and use of the package assembly. Such advantages are particularly desirable for the hostile automotive environment for which the micromachined accelerometer sensing element 20 is intended.

Another distinct advantage of this embodiment is that the leads 30 between the microaccelerometer unit 16 and the substrate 24 need only extend over the projecting edge of the substrate 24 in order to reach the pins 26 which serve as the wire bond sites for the microaccelerometer unit 16. Both pairs of wire bond sites are located near the plane of the planar surface 46 of the cavity, and therefore little vertical projection of the leads 30 is required. The short distance between the wire bonding sites also facilitates the automated wire bonding procedure employed for attaching the leads 30 to the wire bond sites and minimizes any electromagnetic interference concerns.

A further advantage is that the hybrid thick film circuitry remains accessible after being mounted within the cavity until the passivation treatment is applied. Such an advantage allows for final trimming of the resistors in the circuitry for the purpose of correcting any signal output errors resulting from manufacturing and processing of the individual elements of both the circuitry and the micromachined accelerometer sensing element 20 due to tolerances and thermal or mechanically induced stresses.

The above structural characteristics minimize the development of extraneous vibrations and mechanical stresses and their increase in the vicinity of the micromachined accelerometer sensing element 20. As a result, the micromachined accelerometer sensing element 20 responds almost exclusively to the vehicle dynamics associated with acceleration and deceleration.

It will be readily observed by those skilled in the art that there are other parameters which can achieve vibrational and mechanical stress isolation, such as the specific processes used, the thicknesses of the different materials used, and the specific geometry of housing 14 and backplate 12.

Claims

1. An accelerometer assembly comprising a housing (10) including a cavity comprising a lower surface (46) lying along a plane (46) and a recess (34) extending below the plane; an accelerometer sensing device (16), for producing an output signal, disposed in the recess and including a plurality of sensor wire bond sites (26) adjacent the plane; output circuitry (24) for outputting the output signal from the accelerometer assembly, the circuitry being disposed on the lower surface of the cavity so as to extend over a portion of the accelerometer sensing device and including a plurality of circuitry wire bond sites adjacent the plane and proximate the sensor wire bond sites (26) of the accelerometer sensing device; and a plurality of electrical conductors (28,30) for electrically connecting the sensor wire bond sites (26) to the circuitry (24).

2. An accelerometer assembly according to claim 1, wherein the output circuitry (24) comprises hybrid thick film circuitry.

3. An accelerometer assembly according to claim 1 or 2, wherein the output circuitry (24) is secured to the lower surface (46) and the accelerometer sensing device (16) is secured

within the recess.

4. An accelerometer assembly according to claim 1, 2 or 3, wherein the housing (10) comprises a backplate (12) forming the lower surface and the recess; and a plastic enclosure (14) secured to the backplate so as to form the cavity.

5. An accelerometer assembly according to claim 4, wherein the backplate (12) is made of aluminium.

6. An accelerometer assembly according to any preceding claim, comprising a plurality of electrical terminals (44) extending through the housing and being electrically connected to the output circuitry.

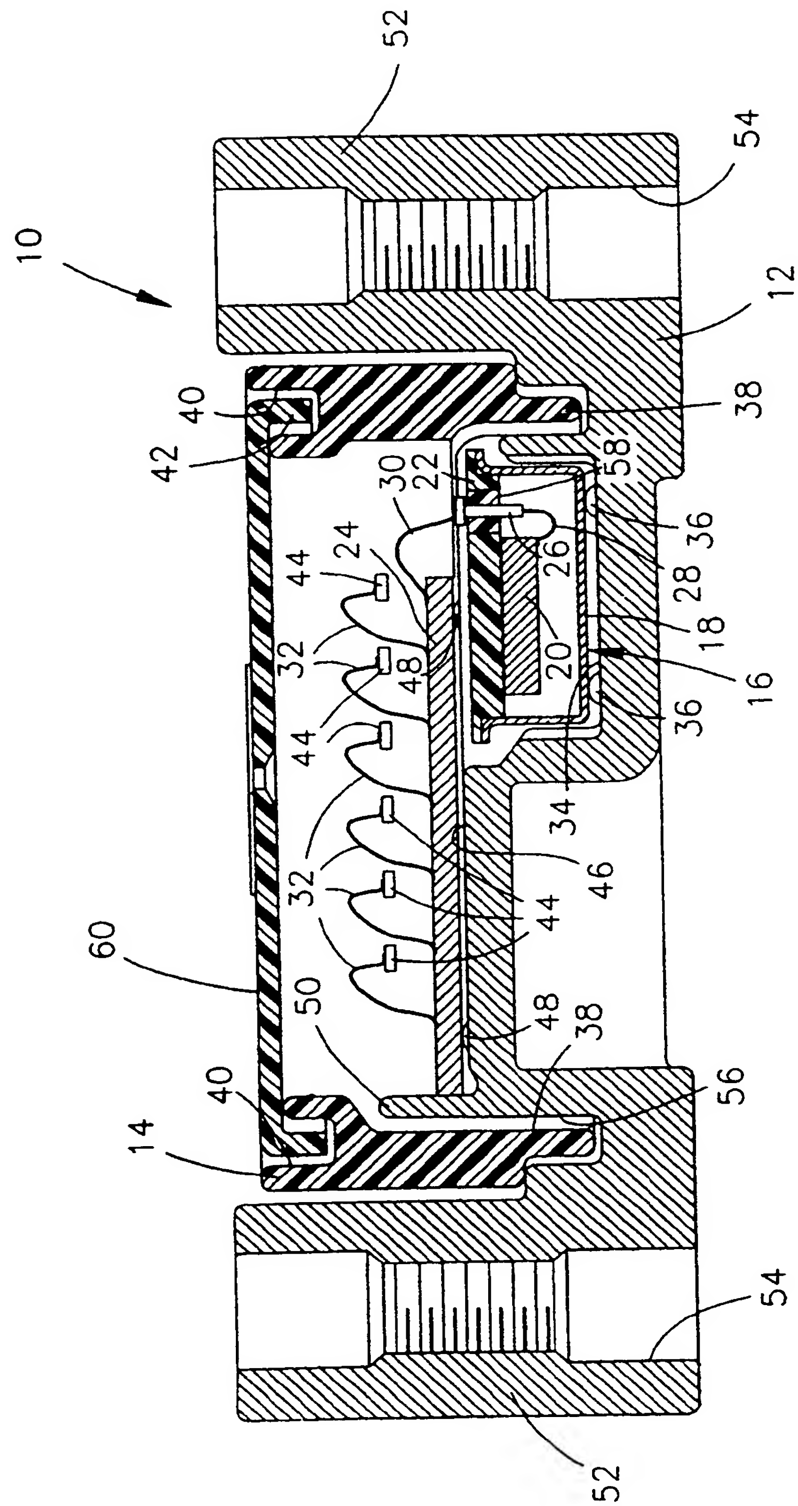
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FIG.1

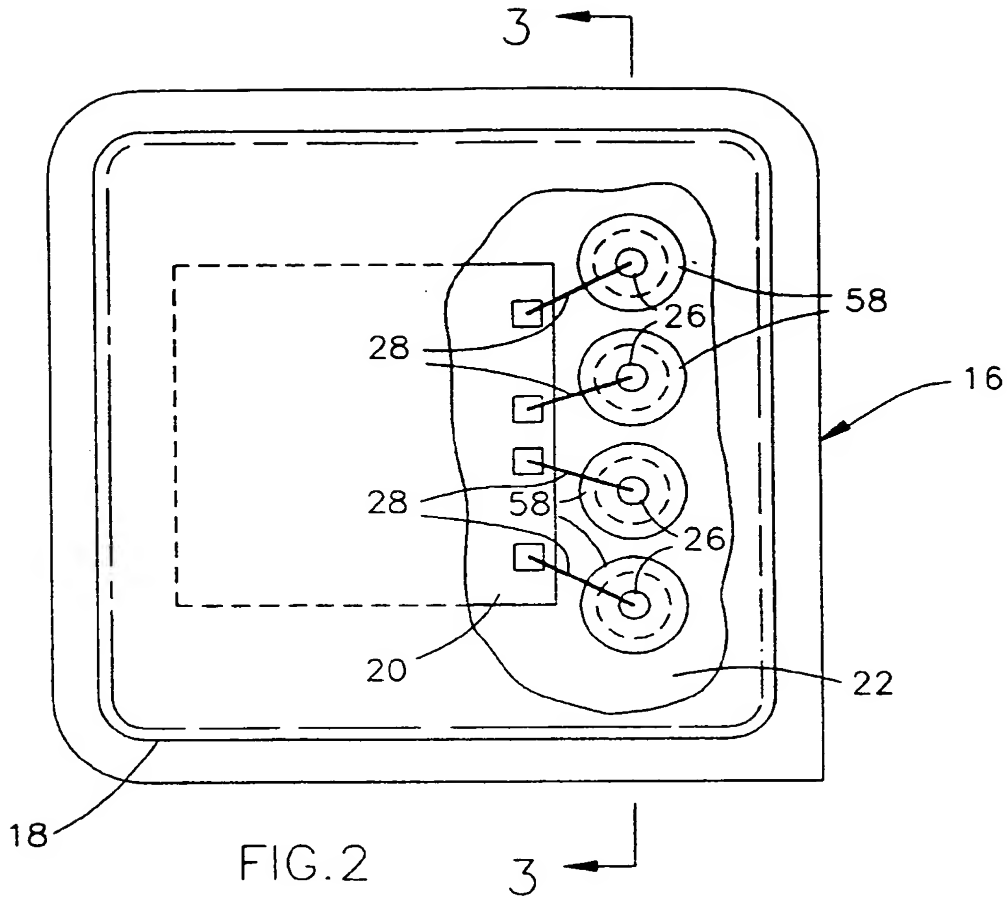

FIG.2

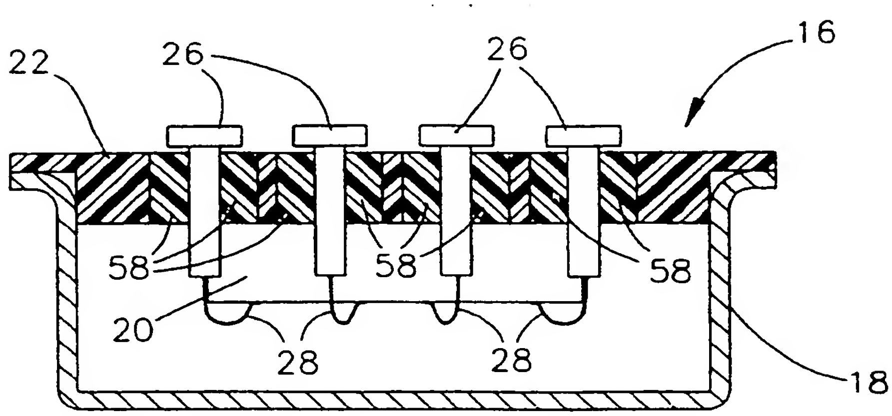

FIG.3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 20 2818

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-4 700 973 (GADEMANN ET AL) * column 4, line 48 - column 5, line 13 * * column 5, line 34 - line 43 * * abstract; figures 1,4,5 *	1-4,6	G01P1/02 H05K5/00 B60R21/00
A		5	
A	DE-A-3 918 407 (MBB) * column 2, line 45 - line 62 * * figures 1,2 *	1-6	
A	WO-A-9 000 482 (NORTON) * abstract; figures 5-7 *	1,2	
A	EP-A-0 332 715 (MBB) * abstract; figure 1 *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G01P H05K B60R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05 FEBRUARY 1993	JONSSON P.O.

CATEGORY OF CITED DOCUMENTS

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